SPECIFICATION

TITLE

"ROTATING ANODE WITH A MULTI-PART ANODE BODY OF COMPOSITE FIBER MATERIAL, AND METHOD FOR MAKING SAME"

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention concerns a rotating anode for an x-ray tube of the type having an anode body composed of composite fiber material, mounted in a bearing system, that has a target surface with a focal ring and fibers with particularly high heat conductivity, with an axis-proximal cooling system associated with the anode body. The present invention also concerns a method producing such a rotating anode.

Description of the Prior Art

X-ray tubes with rotating anodes are known from Krestel, "Bildgebende Systeme für die medizinische Diagnostik", pages 157f, in which the anode plate is composed of a molybdenum alloy. An x-ray-active cover layer made of a tungsten-rhenium alloy is applied to the base body. A graphite body is mounted under the anode plate for heat storage, dissipation and radiation, such that the anode plate is formed of a composite of Mo and C substrate, produced with solder technology, in which the heat spreads (radiates) corresponding to the heat conductivities and the heat storage properties. The WRe alloy of the cover layer can possess a thickness of 0.6 to 1.6 mm.

In x-ray tubes, one of the substantial technical challenges is the heat removal from the focal spot and the distribution of the heat of the focal spot to larger surfaces by rotation of the anode, which is exposed to high mechanical stresses from the rotation and from thermo-mechanical loads. Furthermore, in particular for application

in computed tomography (CT), the usually heavy anode weight is a disadvantage since, due to the typical centrifugal forces resulting in CT from the device rotation, high stressing of the rotating anode bearing results from the heavy anode weight.

Therefore, in German patent application 102 29 069.5 a rotating anode with a basic body made of carbon fiber materials (CFC) is proposed in which fibers with particularly high heat conductivity effect an advantageous heat removal from the focal spot path of x-ray rotating anode tubes to an internally cooled bearing system.

A rotating anode for an x-ray tube, with an anode body composed of composite fiber material held mounted in a bearing system is known from United States Patent No. 5,943,389 having a target surface with a focal ring and fibers with particularly high heat conductivity. An intermediate layer is applied to the anode body, on which a number of aligned carbon fibers are applied, on which in turn the focal ring is applied. The aligned carbon fibers serve to improve the heat removal from the focal ring into the anode body.

German OS 199 26 741 discloses a liquid-metal slide bearing with a cooling tube for a rotating anode, whereby the cooling medium flowing through the slide bearing absorbs and transports away the heat incidental in the operation of the x-ray tube, that arrives in the slide bearing from the anode.

In the abstract for JP 6 1022 546, a method is described to produce a rotating anode that is fashioned from formed components of composite fiber material, known as "prepregs."

In such known x-ray rotating anodes, the problem of achieving good heat conductivity still exists.

SUMMARY OF THE INVENTION

An object of the present invention is to design a rotating anode for an x-ray tube of the type initially described, as well as to specify as a production method for such a rotating anode, such that the high temperatures ensuing in the target surface (fashioned as a rotating anode) are directed away from the focal ring more rapidly than in known anodes, so that the anode withstands the thermo-mechanical load for a longer time, or alternatively sustains higher power densities given unprolonged exposure times.

The object is inventively achieved in a rotating anode of the type initially described wherein a majority of the totality of fibers that exhibit particularly high heat conductivity in the longitudinal direction terminate bluntly, both at the focal ring and at the cooling system, such that their abutting faces are in direct, heat-conducting contact both with the focal ring and with the cooling system, so that better dissipation is ensured. Such a CFC basic body can be produced such that the fibers therein optimally transfer the heat to an axis-proximal cooling surface without geometrically expanding the dimensions that are typical today for x-ray tubes.

More than 80% of the fibers with high heat conductivity in the longitudinal direction, particularly advantageously substantially all of these fibers, inventively terminate bluntly both at the focal ring and at the cooling system.

With regard to the use of the high longitudinal heat conductivity, it has proven to be advantageous when the anode body is fashioned as a multipart body, meaning that it is formed of two or more parts, with the individual parts attached to one another with an accurate fitting, such that the inner surface of an external part completely contacts the outer surface of an internal part. The anode body can be inventively formed from three parts.

A simpler assembly results when each part of the anode body exhibits an identically sized bore through which the cooling system is placed.

The above object is inventively achieved in a production method for a rotating anode having the steps of creation of at least two cup-shaped or bell-shaped formed components, of which the outer diameter of a smaller of the formed components corresponds to the inner diameter of a larger of the formed components, production of concentric bores of the same diameter d in each of the formed components, combining the formed components by resting within each other and interconnection of the formed components, and connection of the finished body to the cooling system.

The interconnection of the formed components and/or the connection of the finished body to the cooling system inventively can ensue in the framework of the overall assembly, for example by carbonization or by soldering.

DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a blank of known anode body.

Figure 2 illustrates a processed rotating anode with the anode body of Fig. 1 and a cooling body.

Figure 3 shows a first blank for an anode in accordance with the invention.

Figure 4 shows a first processed formed component for an anode in accordance with the invention.

Figure 5 shows a second blank for an anode in accordance with the invention.

Figure 6 shows a second processed formed component for an anode in accordance with the invention.

Figure 7 shows a third blank for an anode in accordance with the invention.

Figure 8 shows a third processed formed component for an anode in accordance with the invention.

Figure 9 shows a rotating anode with joined, processed formed components and a cooling body in accordance with the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

An obvious approach to fashioning a CFC body for a rotating anode is to cause the fibers to terminate on one end at the focal path and to terminate on the other end at the axis-proximal cooling body, as it is described using Figures 1 and 2.

In Figure 1, a blank of an anode body 1 with a focal spot path 2 is shown that is composed of a composite fiber material, for example of a carbon fiber material (CFC) that has heat-conducting fibers 3 with particularly high heat conductivity in the longitudinal direction. The cup-like anode body 1 narrows and tapers in a shaft 4. The anode body 1 exhibits an external diameter D, the focal spot path 2 exhibits a width b, and the shaft 4 exhibits a thickness d.

A processed formed component of a rotating anode with a cooling arrangement is shown in Figure 2 that was generated from a blank. For this, a bore was produced in the center of the anode body 1, through which a cooled bearing system 5 was placed and attached. In the anode body 1, fibers 3 are aligned such that they dissipate heat from the focal spot path 2 applied at an angle in the outer region of the rotating anode above to the cooled bearing system 5. So that all fibers 3 are in contact with the cooled bearing system 5, even the fibers 3 proceeding parallel to the rotation axis, the bearing system 5 must be provided with a flange 6 that exhibits the width b.

If it is desired that all fibers that begin under the focal path end at the cooling surface, and thus optimally use the excellent heat conductivity of the fibers in the

lengthwise direction, then the diameter d of the flange 6 is determined from the focal path outer diameter D and the focal path width b as follows, due to the cross-section constant of the total amount of the fibers:

$$\left(\frac{D}{2}\right)^2 - \left(\frac{D}{2} - b\right)^2 = \left(\frac{d}{2}\right)^2$$

or

$$d = \sqrt{Db - b^2}$$

For prevalent focal path geometries in the high-power tube range with a diameter of D = 200 mm and a focal path width of b = 15 mm, the flange diameter d must be relatively large, and that is difficult to realize in conventional tube design. Thus, the example cited above yields a flange diameter of d = 105 mm.

For this reason, in accordance with the invention the anode body 3 is composed of multiple parts, as this is described for three parts using the following Figures.

In Figure 3, a first blank is shown that exhibits an outer diameter D and a focal spot path exhibiting a width of b_1. The blank 7 is formed as a first shell-shaped portion 8 and a shaft-like portion 9 with a diameter d_1. The inner wall of the shell-shaped part 8 exhibits a shape that corresponds to the curve $r_{i1}(x)$, whereby x is the distance of the curve from the upper edge of the blank 7. The outer wall follows the freely-determinable function $r_{a1}(x)$ that determines the outer contour of the anode body.

In order to arrive at the first processed formed component 10 shown in Figure 4 from the blank 7, the shaft-like portion 9 is removed, by producing a bore 11 with a diameter d.

In Figure 5, a second blank 12 with a diameter $D - b_1$ and a focal spot path with a width b_2 are shown. The second blank 12 is also formed with a shell-shaped portion 13 and a shaft-like portion 14 with a diameter d_2. The shape of the outer wall of the shell-shaped portion 13 functionally corresponds to the shape of the inner wall of the part 10.

The second processed formed component 16 shown in Figure 6 is arrived at from the second blank 12 by producing a bore 15 with the diameter d, whereby the portion 14 is removed.

A third blank 17 with an external diameter $D - b_1 - b_2$ and a focal path surface with a width b_3 is shown in Figure 7. The third blank 17 is also fashioned shell-like in the upper portion 18 and has a shaft-like portion 19 with a diameter d_3.

By introducing a bore 20 with a diameter d, at the processed third formed component 21 shown in Figure 8 is produced from the third blank 17, whereby the portion 19 is removed. The shape of the outer wall of this third formed component 21 corresponds to the shape of the inner wall of the second formed component 16.

The three formed components 10, 16 and 21 are now combined and connected with one another, such that a coherent CFC base body 22 results that is shown in Figure 9.

The interconnection of the n mechanically processed formed components can ensue in the framework of a solidification method, for example vy carbonization or via soldering. The connection of the finished body to the cooling surface can be implemented likewise.

A cooling body 23 (that, in the installed state, has a coolant flowing through it), at the surface of which all heat-conducting fibers terminates is slid through the single bore arising in the CFC base body 22, such that the heat is dissipated directly from the focal spot path 2 to the metallic cooling body 23.

As is already described, the CFC base body 22 is composed of n (in this example n = 3) different formed components, in order to be able to use such a rotating anode in tubes of conventional design. The shaping of the blanks 7, 12 and 17 is undertaken such that these fit into one another after the axial, concentric bores 11, 15 and 20 with the diameter d are produced, without the mutual fitting surfaces themselves having to be appreciably processed. Fibers would be split by processing of the fitting surfaces, and the optimal heat flow thus hindered. Such an advantageous shaping of the blanks 7, 12 and 17 is possible by appropriate design of the mold lining from which the blanks are formed (set, knit, woven, prefiled, etc.). If, for example, the desired outer contour of the anode base body is given by $r_{a1}(x)$, whereby $r_{a1}(x) \geq d$, then the outer contour of the mold lining for the outermost of the n formed components 10 is specified by

$$(r_i(x))^2 \approx (r_a(x))^2 - (Db - b^2)\sqrt{1 + (r_a'(x))^2} \quad ,$$

whereby the pitch of the fibers in the shell-shaped region between the focal path and the shaft is accounted for by the term under the root.

This inner contour (specified by $r_{i1}(x)$) of the outermost formed component 10, that is identical to the outer contour of that mold lining on which the outermost formed component was formed, is, for $r_{i1}(x) > d$, at the same time the new outer contour $r_{a2}(x)$ for the second formed component 16, the mold lining for which in this region can then be calculated analogously to the first mold lining.

In the region $r_{a2}(x) < d$, the outer contour of the second formed component 16 is largely freely determinable. It is only to be noted that it must be possible to accommodate the total fiber cross-section of the second formed component 16 within r_{a2}.

The calculations for the further formed components ensue analogously.

So that real solutions to the equations are obtained, it is necessary, as already stated, for the outer contour values always to be selected such that the total fiber cross-section of the respective formed component can always be accommodated within rotating anode. This can be ensured by appropriate selection of the values for b. In other words: the diameter of the outer contour may never be so small that the circular area corresponding to it is smaller than the total cross-section of the fibers of the respective formed component.

The desired geometry of the formed component thus can be easily calculated according to the principle of the cross-section constant of the entirety of the fibers and by suitable selection of the values b_1 through b_n, and can be adjusted to desired values for d when either the outer or the inner contour of the anode base body is determined.

This procedure is possible both

a) given use of blanks that are composed only of a loose fiber composite, whereby in this case suitable clampings are selected for mechanical processing of the blanks, and

b) given blanks that are already partially or are ultimately impregnated, reinforced, infiltrated, reaction-infiltrated, pyrolized, carbonized or graphited.

The space requirement at the cooling body can be significantly reduced by the inventive device and method. With optimal utilization of the high axial heat

conductivities of all carbon fibers beginning in the focal path, geometries are possible that correspond to the tube designs that are common today, thus resulting in, for example, a diameter of $d = 62$ mm given a diameter of $D = 200$ mm and a width of the individual focal spot paths of $b_1 = b_2 = b_3 = 5$ mm. A retrofitting of anodes with CFC base bodies in conventional tubes thus is also possible with optimal utilization of the high axial heat conductivity of the C-fibers.

In the figures, for clarity only the temperature-conducting fibers 3 are shown. Fibers proceeding in other directions, such as those specified in the patent application 102 29 069.5, naturally can be provided, however are not of fundamental importance for the present invention.

Although modifications and changes may be suggested by those skilled in the art, it is the intention of the inventor to embody within the patent warranted hereon all changes and modifications as reasonably and properly come within the scope of his contribution to the art.